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1 **Is tibial tuberosity-trochlear groove distance an appropriate measure for**
2 **the identification of knees with patellar instability?**

3

4 Caplan, N., Lees, D., Newby, M., Ewen, A., Jackson, R., St Clair Gibson, A. &
5 Kader, D.F.

6

7 **Abstract**

8

9 **Purpose:**

10 Tibial tuberosity-trochlear groove distance (TT-TG) has been regarded as a
11 useful tool for establishing therapeutic choices for patellar instability.
12 Recently, it has been shown that TT-TG negatively correlated with the
13 quadriceps angle, suggesting that if used individually, neither provide a valid
14 measure of instability. This study aimed to compare TT-TG distance between
15 both knees in patients with unilateral instability to assess whether this
16 measurement is a decisive element in the management decisions for patellar
17 instability.

18

19 **Methods:**

20 Sixty two patients (18 male and 44 Female), reporting to a specialist patella
21 clinic for recurrent unilateral patellar instability, were included in the study.
22 Patients underwent bilateral long leg computed tomography scan to determine
23 TT-TG distance in both knees. Tibial tuberosity-trochlear groove distances in
24 symptomatic and asymptomatic knees in the same individual were compared
25 statistically.

26

27 **Results:**

28 Mean TT-TG distance in the symptomatic knee was 16.9 (± 4.9) mm,
29 compared to 15.6 (± 5.6) mm in the asymptomatic knee. Tibial tuberosity-
30 trochlear groove distance was not significantly different between stable and
31 unstable knees (n.s.).

32

33 **Conclusions:**

34 The lack of difference in TT-TG distance between stable and unstable knees
35 suggests that TT-TG distance alone may not be a decisive element in
36 establishing therapeutic choices for patellar instability. It should, therefore, be
37 interpreted with caution during clinical evaluations.

38

39 **Keywords:** tibial tuberosity, trochlear groove, instability, knee, patella,
40 dislocation

41

42

43

44 **Conflict of interest**

45 No funding was received for the conduct of this study and the authors declare
46 that they do not have any conflict of interest.

47

48

49 **Level of evidence: 2**

50 **Introduction**

51

52 Patellar dislocation is painful and debilitating, most often affecting young
53 active females, most often affecting young active patients [1]. Recurrent
54 dislocations have a well-documented association with cumulative damage to
55 the patella femoral joint and predictably have a significant, long-term impact
56 on the quality of life of those affected [14].

57

58 A range of factors have been associated with patellar instability including
59 trochlear dysplasia, quadriceps dysplasia, patella alta, and tibial tuberosity-
60 trochlear groove (TT-TG) distance [9,16]. In addition to TT-TG distance, other
61 lower limb bony malalignments, such as increased external tibial torsion
62 [11,28], or increased quadriceps angle (Q angle) [1,27,30], have been linked
63 to patellar instability.

64

65 The TT-TG distance has been proposed to radiographically assess the
66 alignment of the trochlear groove to the tibial tuberosity [9,16]. As with the Q
67 angle [7,10], some have reported an increase in TT-TG distance in patients
68 with patellar instability [2,3] and a threshold of 20mm has been suggested as
69 an indication for surgical intervention [9]. However, the reliability of TT-TG
70 distance has also been recently questioned [18], and the validity of the TT-TG
71 distance, if used alone, has recently been questioned [11]. Despite this, a
72 high TT-TG distance is often used by surgeons to indicate the need for medial
73 tibial tuberosity transfer to correct malalignment within the patellofemoral joint
74 [8].

75

76 To date, no studies have directly compared the TT-TG distance in
77 symptomatic and asymptomatic knees in patients with unilateral recurrent
78 patellar instability. In order to further assess the validity of TT-TG distance in
79 indicating patellar instability and its appropriateness in indicating highly
80 invasive surgical interventions, this study, therefore, aimed to compare TT-TG
81 distances between knees in this patient group. Based on our clinical
82 experience of seeing and scanning a large number of patients with patella
83 dislocation, it was hypothesised that TT-TG distance would not be significantly
84 different between symptomatic and asymptomatic knees in this population.

85

86

87 **Material and Method**

88

89 Radiographic data collected prospectively as part of routine clinical practice
90 were assessed retrospectively for patients reporting to a specialist patella
91 clinic for recurrent unilateral patella instability. Data were available for 62
92 patients, of which 44 were female and 18 were male. The mean (\pm SD) age of
93 the patients was 25.5 ± 8.7 years at the time of their attendance at the clinic.
94 Only patients with recurrent unilateral patellar instability were included in this
95 study. Patients were classed as having recurring unilateral patellar instability
96 if they had previously had two or more dislocations to the same knee. Patients
97 were excluded if they had previously undergone a knee realignment surgical
98 procedure such as a tibial tuberosity transfer.

99

100 A full history and examination was undertaken in clinic, along with plain film
101 radiographs. This was followed by bilateral long leg computed tomography
102 (CT) scan (MX8000 CT Scanner, Philips) to determine TT-TG distance in both
103 the symptomatic and asymptomatic knee in each patient [6]. Computed
104 tomography scans were performed with the patient supine. Their knees were
105 fully extended, their quadriceps were relaxed and their feet were placed in a
106 neutral rotation. Patients lay on a wooden plinth, which had a perpendicular
107 wooden section under the feet.

108

109 The feet were strapped to this foot section of the board to ensure they
110 maintained the correct position during the scanning procedure. Axial CT
111 sections were taken through the proximal femur, knee joint, proximal tibia and
112 ankle. These had channels of 16 9 0.625, slices of 1.4/0.7 mm, in high
113 resolution, with 140 kV, 300 mAs and a rotation time of 0.75 s. To measure
114 the tibial tuberosity–trochlear groove distance axial sections depicting the
115 deepest part of the trochlear groove and the centre of the tibial tuberosity
116 were superimposed. Using a General Electric workstation, a line was drawn
117 on the posterior margins of the femoral condyles, a second line at right
118 angles from the posterior margins of the femoral condyles such that it
119 passed through the centre of the trochlear groove, and a third line was drawn
120 from the centre of the tibial tuberosity such that it dissects the second line at
121 right angles. The length of this third line was the TT-TG distance (Figure 1).
122 The distance was recorded to the nearest tenth of a millimetre. All
123 measurements were performed by a single experienced musculoskeletal
124 consultant radiologist. Test-retest reliability was determined by measuring

125 TT-TG distance in 20 knees twice. The order of measurements was
126 randomised and the radiologist was blinded to the images being used to
127 remove bias. Test-retest reliability was determined using the intraclass
128 correlation coefficient, which was 0.98.

129

130 **Statistical Analysis**

131 Based on previously published data comparing TT-TG distance between
132 asymptomatic knees and those with mild instability [19], an *a priori* power
133 calculation was performed ($\alpha < 0.05$, power = 95%) which suggested a
134 minimum sample size of at least 42 patients. All data were checked for
135 normal distribution using Q-Q and box plots. Tibial tuberosity-trochlear
136 groove distances were then compared statistically between symptomatic and
137 asymptomatic knees using paired samples t tests. 95% confidence intervals
138 were determined and the threshold for statistical significance was set at
139 $p < 0.05$. All statistical tests were performed using SPSS version 19. The
140 number of patients who showed a TT-TG distance that was greater in the
141 symptomatic side, the same in both knees, and greater in the asymptomatic
142 side were also determined and reported as a percentage of the total sample.
143 The study was approved as an audit by the Gateshead Health NHS
144 Foundation Trust research committee.

145

146 **Results**

147

148 All data were normally distributed. Thirty nine (63%) right knees were
149 symptomatic and 23 (37%) left knees were symptomatic. Thirty five (56%)

150 patients reported first dislocating their knee as a direct result of a traumatic
151 injury. Thirteen (21%) patients had trochlear dysplasia, 17 (27%) patients had
152 medial patellofemoral ligament dysfunction, 7 (11%) patients had patella alta,
153 4 (6%) patients had a synovial plica, and 8 (13%) patients had signs of
154 osteoarthritis. Mean TT-TG distance in the symptomatic knees was 16.9
155 (± 4.9) mm, compared to 15.6 (± 5.6) mm in the asymptomatic knee, with a
156 mean difference of 1.3mm (95% confidence interval = -0.5 - 3.2 mm). Tibial
157 tuberosity-trochlear groove distance was not significantly different between
158 symptomatic and asymptomatic knees ($t(122)=1.404$, $p=n.s.$).

159

160 Four (6%) patients had the same TT-TG distance in symptomatic and
161 asymptomatic knees. Thirty two (52%) patients had a TT-TG distance that
162 was greater in the symptomatic knee than in the asymptomatic knee, and 24
163 (39%) had TT-TG greater in the asymptomatic knee.

164

165

166 **Discussion**

167

168 The most important finding of this study was that TT-TG distance was not
169 significantly different between symptomatic and asymptomatic knees. As the
170 sample size used far exceeded the minimum required sample size based on
171 the *a priori* power calculation, this lack of difference is unlikely to be due to an
172 underpowered statistical test.

173

174 An accepted normal range for TT-TG distance is 10 – 15 mm [7], although
175 Monk et al [20] suggested that a TT-TG distance of greater than 14.5 mm is
176 potentially unstable. In the patients investigated here with recurrent unilateral
177 patellar instability, the mean TT-TG distance in the symptomatic side was
178 approximately 17 mm compared to approximately 16 mm in the asymptomatic
179 side. Although these were not significantly different, they are both above the
180 threshold for instability suggested by Monk et al [20]. A TT-TG distance of 20
181 mm or greater is considered sufficiently excessive to proceed to surgery [19].
182 Approximately 30% of symptomatic knees showed TT-TG distances of 20 mm
183 or more. Previously, Dejour et al [9] reported 56% of their patients having TT-
184 TG distance greater than, or equal to, 20 mm in the symptomatic knee. The
185 difference in the proportion of symptomatic knees found with TT-TG distances
186 above the 20 mm threshold between the current data and that presented by
187 Dejour et al [9] could be the result of a number of factors. In the current
188 study, only patients with recurrent patellar instability were included. Dejour et
189 al [9] included both patients with recurrent instability and those with a first
190 episode patellar dislocation. Interestingly, approximately 20% of the
191 asymptomatic knees also showed TT-TG distances exceeding this threshold
192 which is in line with the findings of Dejour et al [9].

193

194 The lack of significant difference in TT-TG distance between symptomatic and
195 asymptomatic knees of the same patients supports the notion that the cause
196 of patellar instability is multifactorial. Factors such as the TT-TG distance,
197 patellar shape, patellar tilt, patella alta, trochlear dysplasia, Q angle, and other
198 bony malalignments within the knee are all likely to play some part in the

199 stability of the patellofemoral joint [1,9,11,27,28,30]. Previously, we observed
200 that despite previous reports of increases in TT-TG [2,9,19,20] and Q-angle
201 [15,27] being linked to increased patellar instability, the two variables can be
202 negatively related [6]. The findings of Cooney et al [6], and those presented
203 here demonstrate that in isolation, the usefulness of TT-TG distance to
204 indicate patellar instability is controversial. Despite this, a high TT-TG is often
205 used as an indication for medial tibial tuberosity transfer.

206

207 Measures such as TT-TG distance and Q-angle do not provide direct
208 measures of the congruence between the two articulating surfaces of the
209 patellofemoral joint (i.e. the patella and the trochlear). The TT-TG distance
210 provides a measure of the alignment between the femoral trochlear and the
211 tibial tuberosity. It does not consider the alignment between the articulating
212 surfaces of the patellofemoral joint. On the other hand, the Q-angle gives an
213 indication of the position of the patella with respect to the tibia and pelvis, yet
214 fails to consider the trochlear. In patients with a ruptured medial
215 patellofemoral ligament, for example, the patella would be more laterally
216 positioned with a higher propensity to dislocate. However the TT-TG distance
217 would not reflect this, as tibiofemoral alignments would not be changed
218 [17,23]. With a subluxed or dislocated patella, a normal Q angle might also
219 be observed.

220

221 As unstable knees lead to subluxation of the patellar with respect to the
222 trochlear, then it could be useful to measure the position of the patella with
223 respect to the trochlear, avoiding the use of surrogate measures such as TT-

224 TG distance. Perhaps the radiographical measurement of the lateral distance
225 between the patellar ridge and the deepest part of the trochlear, or the PR-TG
226 distance, is a better reflection of the patella position in relation to the trochlea.

227

228 The usefulness of the TT-TG distance has also been brought into question as
229 it will not identify the location of any patellofemoral malformation [24].

230 Seitlinger et al [24] investigated the use of the distance between the tibial
231 tuberosity and the posterior cruciate ligament, or TT-PCL, in comparison to
232 the TT-TG distance, in the evaluation of tibial tuberosity lateralisation. Their
233 findings supported the notion that a pathological TT-TG distance (>20mm)
234 might not indicate lateralisation of the tibial tuberosity, and that a high TT-TG
235 might not be an appropriate indication for surgical realignment of the tibial
236 tuberosity.

237

238 Whilst the aim of this study was to determine whether TT-TG distance was
239 different between symptomatic and asymptomatic knees in patients with
240 recurrent unilateral patellar instability to determine whether TT-TG distance
241 should be used for indicating surgical intervention, it should be noted that
242 some patients with unilateral instability can develop instability in the
243 asymptomatic knee at a later date. Nikku et al [21] observed that 15% of
244 patients developed contralateral instability at two years after an initial
245 dislocation, and this figure rose to 27% by seven years.

246

247 A limitation of this study was that only TT-TG distance was considered.

248 Patellar instability is likely to be multifactorial, with other factors such as

249 trochlear dysplasia, external tibial torsion, femoral neck anteversion, patella
250 height and medial patellofemoral ligament integrity also potentially influencing
251 stability of the patellofemoral joint [1,9,11,27,28,30]. Future studies should
252 consider the interactions between these factors in patients with patellar
253 instability in order to determine the best combinations of measures to use in
254 informing corrective surgical interventions. A limitation of the TT-TG distance,
255 and potentially other anatomical measures taken from CT images, is that the
256 true anatomical alignments cannot be fully appreciated, as the cartilaginous
257 architecture is not demonstrated. Magnetic resonance studies have clearly
258 documented the difference in bony versus cartilaginous relationship of the
259 patella-trochlear anatomy [4,5,10,12,13,22], and this was explored in detail by
260 Van Huyssteen et al [29], who demonstrated a significant anatomical
261 mismatch between the bony architecture and cartilaginous morphology in
262 patients with trochlear dysplasia. Despite this limitation of CT imaging based
263 measures of TT-TG, however, any errors would likely be similar between
264 symptomatic and asymptomatic knees in this study as both knees were
265 evaluated in each patient.

266

267 The finding of a lack of difference in TT-TG distance between the
268 symptomatic and asymptomatic knees of patients with recurrent unilateral
269 patellar instability suggests that surgeons should not base their decision to
270 perform highly invasive surgical interventions such as medial tibial tuberosity
271 transfer to restore correct alignment within the patellofemoral joint purely on
272 the basis of a high TT-TG distance. Whilst good results have certainly been
273 reported for osteotomy and medialisation procedures [8,25,26], incomplete

274 assessment means the decompensatory malefactor may remain
275 unacknowledged and thus untreated, leaving the avenue open for chronic
276 instability. It would thus be prudent to carefully consider the role of the choice
277 of imaging investigations as well as the indications for medialisation
278 procedures where MPFL reconstruction, capsular plication or trochleoplasty
279 may be more appropriate.

280

281

282 **Conclusions**

283

284 Despite the TT-TG distance being routinely used by many knee surgeons to
285 assess patellar instability, the data presented here show that it can be the
286 same in symptomatic and asymptomatic knees of patients with recurrent
287 unilateral patellar instability. This brings into question the usefulness of the
288 measure in the evaluation of these patients, especially for indicating surgical
289 interventions such as medial tibial tuberosity transfer.

290

291

292

293

294

295 **References**

296

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- 390
391
392

393 **Figure captions**

394

395 Figure 1. Axial computed tomography scan showing measurement of the tibial
396 tuberosity-trochlear groove distance in the left knee.

397

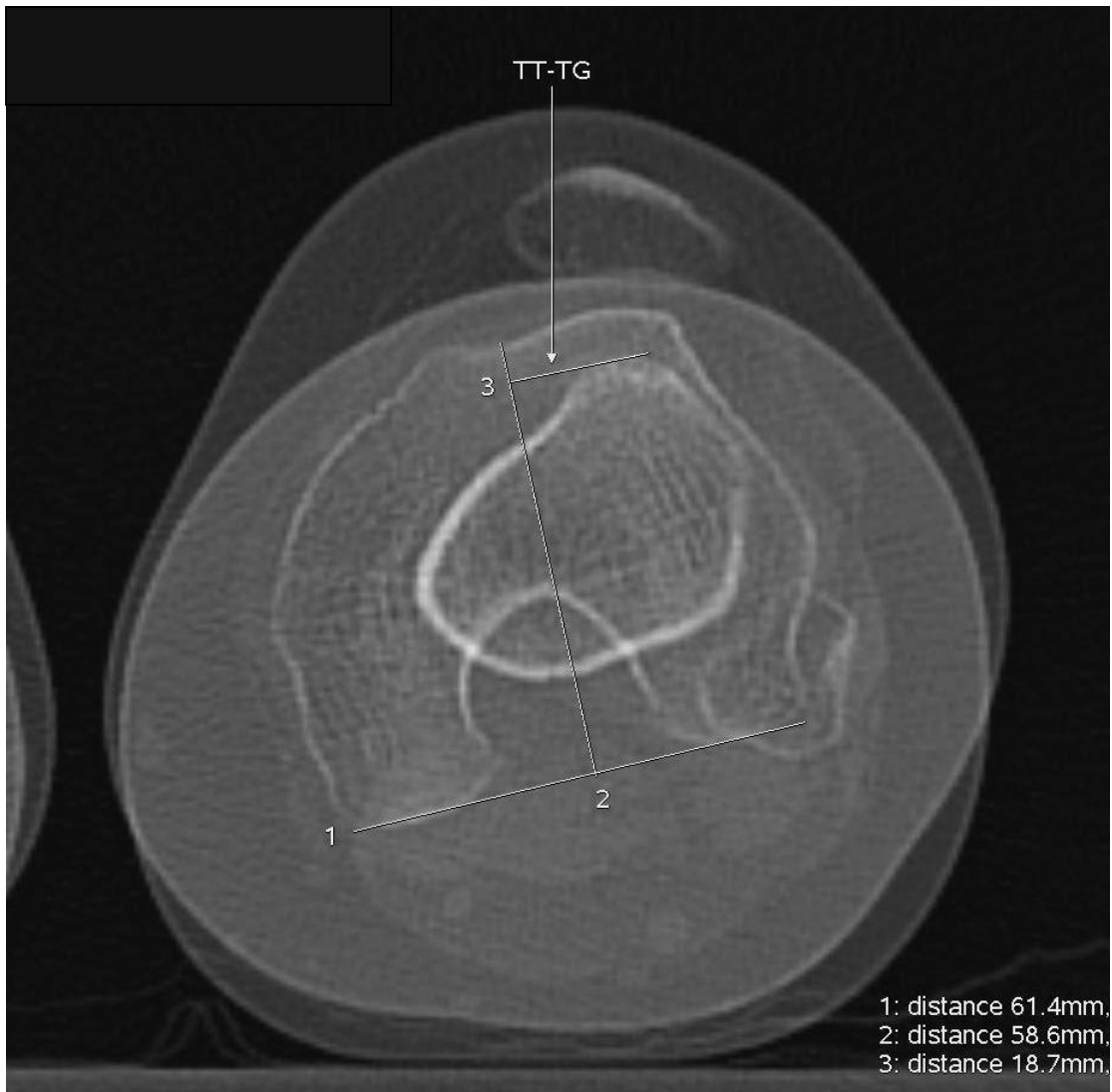
398

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401

402 **Figure 1**



403